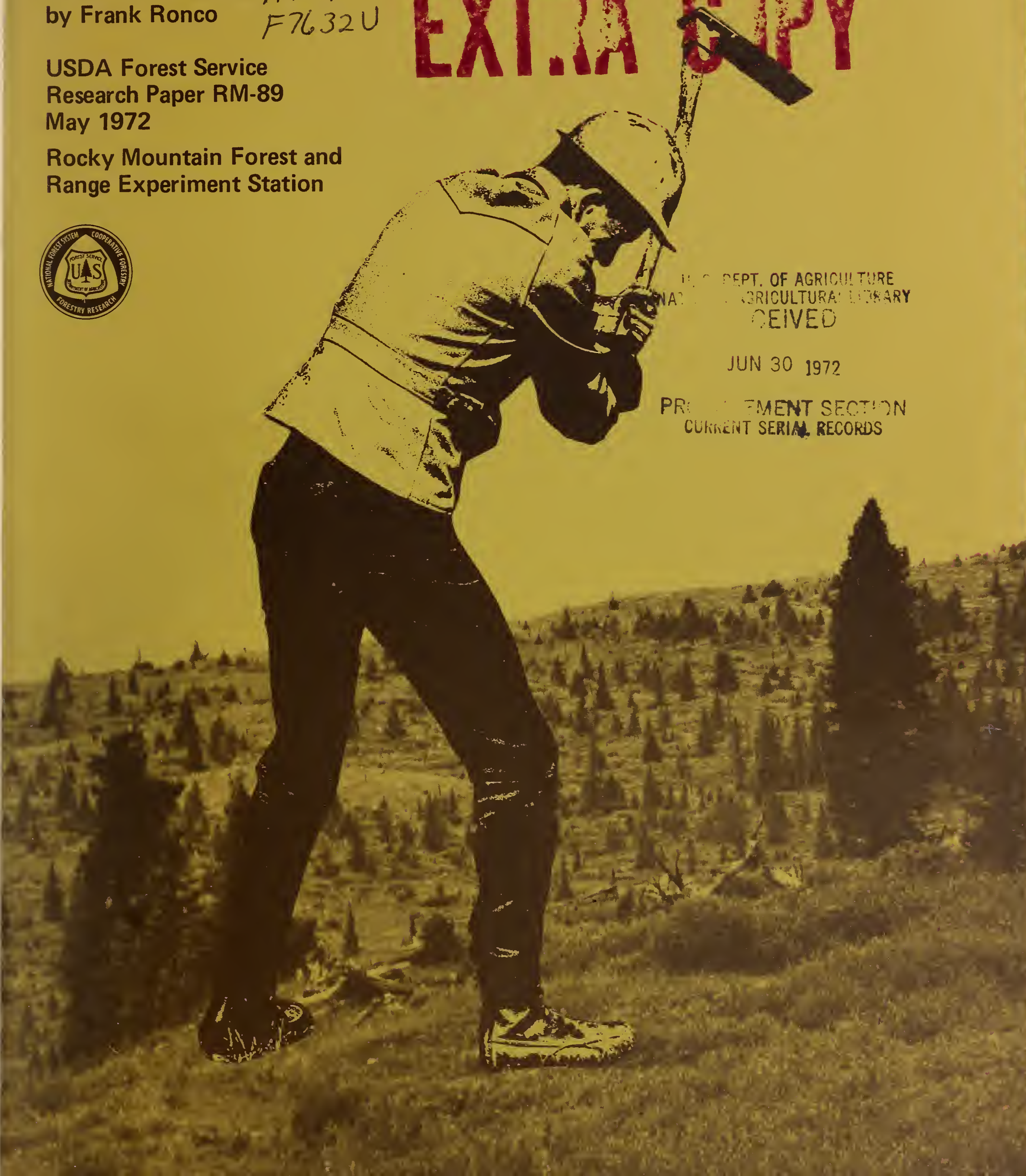
PLANTING ENGELMANN SPRUCE

by Frank Ronco

USDA Forest Service
Research Paper RM-89
May 1972

Rocky Mountain Forest and
Range Experiment Station



Abstract

Recommendations are provided to aid the forest manager in regenerating Engelmann spruce by planting in the central and southern Rocky Mountains. Reforestation operations covered include storage, transportation, microsite selection, site preparation, planting, plantation protection, and recordkeeping. The physiological and silvicultural requirements of spruces are discussed with respect to the harsh environment of the spruce-fir zone so that planting principles can be better understood.

Keywords: Picea engelmannii, planting, artificial regeneration.

ABOUT THE COVER:
High-elevation burn on the eastern approach of Vail Pass in central Colorado. The spruce-fir forest covering the area was destroyed by fire near the turn of the century, but natural regeneration is establishing slowly. Planting may be necessary to shorten the reforestation period on such areas, particularly where seed-producing trees are sparse or absent.

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Contents

For convenient field use, the planting practices and recommendations in this Research Paper have been published separately in a smaller format (5½ by 8½ inches) as USDA Forest Service Research Paper RM-89A, "Planting Engelmann Spruce—A Field Guide." Copies of RM-89A are available from the Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80521.

Planting Engelmann Spruce

Frank Ronco

This guide was prepared to provide the land manager with the basic principles of planting Engelmann spruce (Picea engelmannii Parry) in the central and southern Rocky Mountains. Research results are summarized, and the physiological and silvicultural requirements of spruces are discussed with respect to the harsh environment where they grow so that planting principles can be better understood.

Reforestation is essentially a series of events that starts with sowing in the nursery and ends when planted seedlings become established. Interim operations include cultivation, lifting, storage, transportation, site preparation, planting, and protection of the plantation. Thus, a regeneration project is successful only to the extent that each operation accomplishes a common objective which, simply stated, is to keep stock in a vigorous condition. Survival can be jeopardized if any operation does not maintain the necessary conditions required for healthy seedlings.

Although optimum conditions for each operation may not be fully known for spruces, enough information is available to outline procedures that should increase the probability of successful plantations. This guide summarizes specific research on spruce, practices demonstrated and proven successful in other regions (Limstrom 1963, Schubert et al. 1970, Wakeley 1954), and observation and experience.

Physiological and Silvicultural Requirements

Light

Examination of Engelmann spruce plantations established on National Forests as early as the 1910's led Korstian and Baker (1925) to conclude that denuded areas in the spruce-fir zone could be successfully reforested if seedlings were protected by "down logs, stumps, and open brush." Recent studies (Ronco 1970a) showed that such protection is necessary because spruce seedlings are injured by high light intensities—a phenomenon known as solarization—and generally survive poorly when exposed to full sunlight for prolonged periods. Chlorotic (yellow-colored) foliage is the most common visible evidence of light injury to seedlings planted in the open.

Light injury has often been observed in many other shade-adapted or tolerant species, and appears to be related to the photosynthetic behavior of such plants. Shade plants, including spruces, have lower maximum photosynthetic rates and their photosynthetic mechanisms become light saturated at lower intensities than sun plants (intolerant species). Furthermore, they become increasingly susceptible to solarization the higher the light intensity increases above the saturation point. Open-grown spruce seedlings are particularly vulnerable since they are exposed to light intensities that are three to four times greater than those at saturation during most of the day.

The occurrence of solarization does not depend solely on the intensity of light. Duration of exposure is critical, and other factors, including high leaf temperatures and plant water stresses, may trigger the phenomenon. Thus, while light injury can be avoided simply by shading seedlings, the interrelationship of causal factors complicates prevention measures when all-day shade is now available. Shade during the hottest part of the day benefits planted spruce seedlings, even though they are exposed to full sunlight during morning and evening hours (Ronco 1961, 1970b). Midday and afternoon shade are necessary, probably because seedlings are subjected to higher temperatures and water stresses during these periods.

Water

The internal water balance of seedlings is probably of greater importance for growth and survival than any other plant-factor relationship. Water deficits alter the chemical composition of seedlings and decrease the rate of their physiological functions (Kramer and Kozlowski 1960). Deficits are created whenever water loss from transpiration exceeds water uptake by roots. Thus, water stresses may result from (1) lack of precipitation (drought); (2) high transpiration rates; or (3) reduced water uptake caused by cold soils, poor root conditions, or low moisture-holding capacity of soils.

Newly planted seedlings are most likely subjected to some water stress, but laboratory and field studies suggest that dehydration is not the major cause of mortality observed in spruce plantations (Ronco 1970a). Water deficits in seedlings probably arise from the combined effects of transpiration and reduced water uptake rather than drought, since precipitation in the spruce-fir zone is generally adequate for seedling survival. For example, soil-moisture measurements in plantations on the White River Plateau in western Colorado during a particularly dry summer showed that moisture at root-zone depth was at or near field capacity throughout the summer and early fall. On the other hand, root initiation and elongation in newly planted seedlings is retarded due to low soil temperatures. Thus, normal transpiration losses coupled with slow root development may create water deficits in planted seedlings until roots become established.

More favorable water balances in seedlings can be obtained by using protective cover to reduce transpiration rates, which might otherwise be accelerated by exposing foliage to wind, or the heating effect of direct sunlight on needles. Little control can be exerted over those factors relating to water uptake, except to discard seedlings with spindly root systems. Similarly, precipitation is not controllable, but the amount of moisture available for seedling use can be increased by avoiding soil conditions that decrease water storage capacity (excessively rocky areas) or create a heavy drain on stored water (heavily sodded areas).

Temperature

Engelmann spruce is adapted to a cool environment, but new growth is still very sensitive to freezing temperatures, which commonly occur several nights during any growing season. All new growth on mature trees and seedlings—either natural or planted—is frequently killed when air temperatures are below freezing and heat loss from foliage is increased because of radiation to the clear nighttime sky (Ronco 1967). Both the severity and frequency of frost injury can be lessened, however, by reducing such radiant heat loss from seedling foliage and surrounding soil. Stumps, logs, slash, or a cover of live vegetation are effective barriers.

Daytime air temperatures, which rarely exceed 75° F. in the central Rocky Mountains, are probably not high enough to directly injure planted seedlings. However, elevated needle and soil-surface temperatures resulting from exposure to direct sunlight increases water losses from both seedlings and soil. Fortunately, the same type of cover that protects against freezing injury also tends to reduce water losses.

Planting Operations and Recommendations

Planting Stock

Korstian and Baker (1925) recommended 3-1 or 3-2 stock (top height about 4 to 6 inches and root length about 9 to 13 inches) with a good balance between top and root for planting in the Intermountain Region. They did not consider 3-0 stock suitable, even though of acceptable size, because it lacked fibrous root development. Schubert et al. (1970) suggested that spruce planting stock in the Southwest should have a stem caliper of 0.10 inch and well-developed tops and roots. No research has been conducted specifically to determine the size of spruce seedlings best suited for planting in the central and southern Rocky Mountains.

Observation of plantations on the White River National Forest, involving different age classes and sizes of stock over several years, suggested there may be some advantage to planting the larger seedlings from ungraded nursery stock. However, the studies also indicated that shading and good planting practices were more important than seedling size alone.

Spruce seedlings grown in the nursery, particularly from Colorado and Wyoming seed sources, have consistently varied widely in growth behavior; seedlings in individual beds may vary in height by several hundred percent. The smaller seedlings, while apparently healthy, appear to have slow, genetically controlled growth rates, which probably affect their ability to become quickly established when outplanted.

Grading should include provisions to cull the obviously small seedlings, as well as those that are too large to handle and plant practically. The guidelines below are based on limited experience in the Rocky Mountain Region, U. S. Forest Service; local conditions and experience may allow modification.

Recommendations:

1. Tops should not be shorter than 3 to 4 inches; they should be well developed with not less than two to three branches.
2. Roots should not be shorter than 5 to 6 inches; they should be compact, fibrous, and well developed with several lateral roots.
3. Tops and roots should be well balanced (low shoot/root ratio).

Planting Season

The time of year when seedlings are planted influences the success of plantations, particularly under short growing seasons and difficult environmental conditions. The probability of a successful spruce plantation is greatest when seedlings are planted in the spring. Soil moisture following snowmelt is maximum and weather conditions are favorable. Furthermore, seedlings have the benefit of an entire growing season to develop and overcome the shock of planting. To be most advantageous, however, seedlings should be planted in spring immediately after snowmelt; delay should be only long enough for free water to drain from the soil so that it can be properly packed around seedling roots. In many instances, roads will have to be cleared of snowdrifts to make most efficient use of the short planting season, and to plant under optimum soil-moisture conditions.

Spring plantings should be organized to take advantage of the conditions afforded by aspect. Plant southwest- and south-facing slopes first; east and north slopes last. In addition to facilitating access to planting areas, such scheduling will tend to lengthen the planting season by extending the period over which soil-moisture conditions are more favorable.

Local experience and judgment will be needed to determine when planting should be terminated in the spring, or temporarily suspended because of unfavorable planting conditions. The planting season in the spruce-fir zone normally extends from about May 25 to June 25. In years of late snowmelt, however, the season may be extended somewhat, but no seedlings should be planted after July 10 or they will not have sufficient time to harden off. The length of the planting season depends primarily on available soil moisture, but unseasonably high temperatures would also be sufficient reason for terminating planting because of the adverse effect on transpiration. Similarly, planting may be temporarily halted during the regular planting season because of unseasonably warm temperatures, especially if they are forecast for several consecutive days.

Summer and fall planting are **not** recommended in the spruce-fir zone for several reasons. **First,** good stock would not available. Seedlings lifted in the spring and stored for summer planting would be subjected to the adverse effects of prolonged storage, whereas nursery stock lifted in early fall before the seedlings are fully dormant would be in poor physiological condition. **Second,** by the time nursery seedlings can be safely lifted in late October or November, the high-elevation sites are generally inaccessible. **Third,** in those instances where good weather does permit fall planting, it also makes success less certain. Without a protective cover of snow, seedlings may be desiccated (winterkilled) because of an imbalance between transpiration and water uptake. Furthermore, cold soil at this time of year retards or even prevents root growth, and seedlings do not have the benefit of a well-developed root system to reduce the possibility of winterkill. Finally, seedlings will break dormancy if planted before temperatures and photoperiods prevent growth, but they are subjected to freezing fall temperatures nearly every night before shoots can fully develop—normally about 7 to 8 weeks. Subsequent frost injury to the new growth substantially increases mortality, and growth of surviving seedlings is lessened the following spring.

Recommendations:

1. Planting should be completed before June 25. Do not extend planting season beyond July 10.
2. Plant southwest- and south-facing slopes first; east and north slopes last.
3. Terminate spring planting when soil moisture becomes depleted, or temperatures are unseasonably high.
4. Temporarily suspend planting during the regular season if temperatures are unseasonably warm, particularly on clear days with dry winds.

Storage Principles

Nearly all planting operations in the Rocky Mountains require seedlings to be lifted from the nursery while they are still dormant, and stored until planting areas are free of snow. Dormancy must not only be maintained during storage, but transpiration and respiration also must be curtailed to prevent water stress and excessive loss of stored food reserves. These latter objectives are particularly important because first growth after planting depends mostly on stored food reserves, and water deficits alter the chemical composition and physiological functions of seedlings.

Seedlings should be treated as dormant plants, not only while stored at the nursery, but also during transit and periods of local storage. Optimum storage conditions—temperature between 34° and 36° F. and relative humidity over 90 percent—may not be readily attained outside the nursery, but for periods of 1 week or less, temperatures around 40° F. and humidities near 50 percent can be tolerated.

Molding is a major problem during extended storage of seedlings in nurseries (Hocking and Nyland 1971), but it is not likely to be a threat during short storage periods encountered in the field. Factors involved in molding include high relative humidities, free water on foliage, high storage temperatures, duration of storage, species susceptibility, and the presence of inoculum in soil adhering to foliage or packing materials.

Extended storage.—Adequate facilities are available at the nursery for storage extending over several weeks or a few months. Even though low temperatures depress physiological activities, respiratory losses of food reserves in spruce seedlings may still be high enough after long storage to reduce survival.[2]

Recommendations:

1. Spruce seedlings should not be stored over 3 months.
2. Extended storage should not be attempted locally since adequate facilities and trained personnel are not readily available.

Transit storage.—Methods of transporting stock will depend on ambient air temperatures and hauling distance. Long-distance transport under warm to hot temperatures will require controlled-temperature refrigeration units or insulated containers which can be held under 40° F. with ice. For short trips up to a few hours' duration, when air temperatures are cool to moderate, seedlings can be transported most conveniently in trucks with enclosed beds.

If open-bed trucks are used and seedlings are packaged in bundles, care must be exercised to prevent seedlings from drying. Cover the bundles with a tarpaulin that allows air to circulate over seedlings, but block high-speed, turbulent air flows created by moving vehicles. Use only canvas covers, since plastic materials transmit and trap solar heat. Covers should also be tied securely so that seedlings are not mechanically injured by flapping covers during high-speed travel.

Seedlings packed in sealed bags (polyethylene or polyethylene-lined paper) will not be dehydrated by air movement during transit in open-bed trucks, but cover will still be needed. Unless sealed bags are shaded from direct sunlight, temperatures inside may reach levels that are injurious or even lethal to seedling tissue. Even if the higher temperatures are not directly harmful, they may foster growth of molds.

Temperatures around packaged seedlings transported in enclosed or tarpaulin-covered truck beds can usually be kept low enough by including block ice and wetting the cover before leaving the nursery. Travel can be restricted to nighttime hours if daytime air temperatures are too high.

Recommendations:

1. Maintain temperature of seedlings between 34°-40° F. during transit.
2. Cover bundles or bags carefully with canvas tarpaulins—Do not use plastic—when seedlings are transported in open vehicles.
3. Be particularly careful to keep sealed bags out of direct sunlight.

Local storage.—Storage problems are more severe in the field, because limited facilities on the planting site make temperature control more difficult. Consequently, the maximum number of trees in storage should be limited to a 1-week supply. Well-insulated storage sheds that can be cooled by ice or snow should be used in the absence of mechanical refrigeration (see appendix). If such facilities are not available, cool, moist cellars or even snowbanks would be suitable substitutes, but seedlings should be held for shorter periods because storage conditions will be less favorable.

Solidified carbon dioxide (Dry Ice) is not recommended for cooling storage rooms because gaseous carbon dioxide in high concentrations disrupts the physiological processes of respiration and water transport, and may even be toxic to seedlings in extremely high concentrations. Furthermore, humans may be asphyxiated in tightly sealed storage rooms, particularly if work is performed near floor level, since the heavier carbon dioxide settles and displaces oxygen.

Seedlings must also be protected against freezing while in storage or transit. Although many conifers, including some species of spruce, have been satisfactorily stored at temperatures below 32° F., such storage requires more control than can be maintained under field conditions. Seedlings that are frozen too rapidly or when they are not fully dormant may be seriously damaged.

[2] Ronco, Frank. Food reserves of Engelmann spruce planting stock. (Manuscript in preparation at Rocky Mt. For. and Range Exp. Stn.)

Packing material around roots in bundled trees in storage may require rewetting occasionally to prevent seedling desiccation. To determine the need for water, a small amount of sphagnum moss can be pulled from the bundle and squeezed in the hand; if **any** water is pressed out, the material is sufficiently moist. If it is necessary to prepare moss for planting containers or to repack seedlings from damaged bundles, the proper moisture content can be attained by soaking moss overnight and then draining for at least a half hour.

Recommendations:

1. Maintain temperature between 34° and 36° F.
2. Limit storage to 7 days; where storage temperatures approach or exceed 40° F., then no more than 3 days.
3. Use ice, snow, or mechanical refrigeration to cool storage rooms—do not use Dry Ice.
4. Protect seedlings against freezing.
5. Arrange bundles or bags on racks so that air can circulate around each package—seedlings may overheat if packages are stacked.
6. Take precautionary measures if mold should develop under field storage conditions:
   a. Lower temperature or shorten storage period.
   b. Provide air circulation around foliage.
   c. Keep foliage dry.
   d. Rewet packing material in bundles with a perforated tube, attached to water hose, that will reach roots. Drain excess water.
   e. Do not water seedlings in sealed bags. If bags are damaged and drying is evident, repack seedlings in open-end bundles before rewatering.

Storage in planting containers.—Field personnel will be concerned with individual seedlings for the first time as packaged seedlings are transferred to bags or trays. Exposed seedlings must be protected against desiccation from wind and sun, which would soon kill most smaller roots and seriously decrease survival. Consequently, seedlings should be transferred in sheltered work areas, such as storage sheds, tents erected at the planting site, or clumps of trees when the size of the job does not warrant more elaborate facilities.

Care must also be used in separating intertwined roots of packaged seedlings before they are placed in individual containers. Damage can be lessened if the pulling force during separation is parallel to the stems. For optimum moisture conditions in planting containers, spread seedlings thinly, with roots in contact with alternate layers of moist sphagnum moss. Seedlings can then be easily removed for planting.

Storage in bags or trays is simply an extension of storage begun in the nursery, and is subject to the same moisture and temperature requirements. Packed containers can be kept for several days under the same conditions recommended for bundles, but time becomes critical after containers are issued to planters.

Container-held seedlings cannot be maintained at favorable temperatures for long periods on the planting sites. Planters should minimize the length of time seedlings are kept in containers and place containers in any available shade whenever possible. Water loss can be more easily controlled, but depends largely on proper supervision, experience of planters, and type of container. Experienced planters, who understand the importance of plant-water relations, can satisfactorily use bags without unnecessarily exposing roots of seedlings remaining in the bag as individual trees are removed. Some supervisors have found trays better suited for inexperienced crews because seedlings are extracted more easily. Furthermore, trays of seedlings can also be covered with burlap, thus reducing water loss from transpiration.

Seedlings in containers may become desiccated if packing material around roots becomes dry and is not remoistened with water or snow throughout the day. Free water in containers during this phase of the operation is probably not critical, since roots are not inundated for long periods. However, aeration would be better if planters were instructed to drain water as it accumulates.

Recommendations:

1. Do not expose roots to sun and wind when transferring seedlings from bundles or sealed bags to planting containers.
2. Prevent undue breakage of roots when handling seedlings.
3. Keep roots covered at all times with moist sphagnum moss.
4. Place container in shade whenever possible.
5. Suspend planting operations on clear days with dry winds and high temperatures.
6. Limit the time seedlings are kept in containers on the planting site as suggested for atmospheric conditions shown on the following page:

	Container time on— calm day *	windy day *
	(Hours)	
High humidity:		
Cool (under 55° F.)	8	4
Warm (55°-70° F.)	4	2
Hot (over 70° F.)	2	1
Low humidity:		
Cool (under 55° F.)	2	1
Warm (55°-70° F.)	2	1
Hot (over 70° F.)	1	1

*On clear days, direct radiation will increase the heat load on containers, and shorter holding periods are advisable whenever practical.

Spot Selection

Suitable microsites for planted seedlings frequently have not been utilized because (1) spots were not easily accessible due to slash accumulations, (2) planters were unaware of the silvicultural requirements of spruces, or (3) demands for uniform spacing were unrealistic.

Most planters tend to plant open areas rather than suitable habitats close to stumps and logs because less work is involved. Branches and other debris often hinder access to spots, and once the spot is reached, footing may be insecure or space restrictions limit freedom to use planting tools effectively. Use of suitable spots can be increased by close supervision and training programs that emphasize the impact of solarization and potential water stress on spruce seedlings. Figures 1-8 illustrate effective use of cover in an operational plantation, as well as examples where training and supervision could be intensified.

Protective cover is usually scattered unevenly on spruce plantation sites. Attempts to space seedlings uniformly, even though desirable for full stocking, result in many trees being planted without protection. Planting in the open is usually wasted effort because of the high mortality rate of exposed seedlings. Spacing must be determined, therefore, by the availability of suitable planting spots rather than number of seedlings for optimum stocking. Consequently, seedlings will be spaced irregularly, and plantations will resemble natural stands more closely in that trees will be grouped in patches of variable size.

Recommendations:

1. Plant only those spots where seedlings are protected by stumps, logs, slash, or an open cover of live vegetation (see following section on Site Preparation). The preferred location is on the north side of cover; the east side may be used if preferred spots are unavailable, but avoid spots on the west side of logs where heating is more intense.
2. Knock loose bark from logs and stumps.
3. The seedling should be planted no more than 3 inches from protective cover unless the latter is high enough to cast a wide shadow that will envelop the seedling.
4. Spacing between seedlings should not be less than 4 feet when planting alongside long logs or in areas where protective cover is clustered.
5. Avoid planting in depressions where silt can smother trees.
6. Plant with roots in moist soil—generally, soil is too dry when a handful does not form a ball when squeezed.
7. Select spots that are relatively free of rocks to increase the volume of water-holding soil in the root zone.
8. Avoid planting on small mounds or hummocks, which tend to dry rapidly.
9. Avoid planting in areas with an extensive cover of dense sedge or grass sods (see following section on Site Preparation).
10. Emphasize that additional effort and time required to plant in properly located spots is compensated for by increased chances for survival.

A

Figure 1.—More effective protection with same effort. Seedling in (A) is partially protected by logs placed by planter. By simply reversing order in which logs were positioned (B), the seedling was shaded more fully by the log to the south (at left of center). Seedlings can be given maximum protection when logs are arranged in a "V" configuration, with the point toward the south, since shade is provided from morning through afternoon.

B

A

Figure 2.—Branches or small-diameter logs provide little or no shade. Small logs, (C), might offer enough protection if they were arranged differently. Similarly, the preferred microhabitat

B

C

on the north side of the log, (D), could have been improved by laying another log on the existing one so that the seedling would be shaded from the west (right of photograph), and by moving existing log closer to the seedling.

D

A

Figure 3.—Conscientious attempt at protection fails. Planter spent considerable effort and time erecting tepee cover (A, reconstructed for illustration), but structure collapsed (B), leaving seedling exposed to full sunlight. Structures should have sufficient strength to withstand the weight of accumulated snow.

B

Figure 4.—Error in spot selection. Seedling planted on the west side of a small log is fully exposed to radiation most of the day, especially during the hot afternoon hours.

Figure 5.—Shade from log fully utilized. Seedling is within 3 inches of the east side of log. Such a spot would be optimum with little additional effort expended by laying a nearby log across the existing one so that seedling is also shaded from the south.

A B

Figure 6.—Cover still effective when seedling not close to log. Seedlings can be planted farther than 3 inches from large logs, (A), or those elevated above the ground (B).

Figure 7.—Vegetation may be effective cover. Caution should be used, however, when providing live shade until more experience is gained concerning the effect of competition for moisture.

Figure 8.—Unnoticed hazards may jeopardize survival. The seedling has been properly planted with adequate protection, but it could be smothered if bark sloughs from log. With very little effort, bark can be knocked off with a mattock.

Site Preparation

The objective of site preparation is to manipulate some of the environmental factors affecting tree growth and survival—namely, soil moisture, light, and temperature of soil and air. The degree of control attempted will depend on local climate, soil properties, topography, vegetation density, and most importantly, the physiological and silvicultural requirements of the species planted. Obviously, without prior knowledge of seedling needs, attempts at site preparation could produce detrimental as well as beneficial effects. Site preparation is further complicated in that individual environmental factors cannot be manipulated without affecting others.

Site preparation measures for spruce plantations probably require more consideration than for most other species because of the complex relationship between the environment and seedling requirements. For example, warmer soils and increased moisture availability accompanying complete vegetation removal would benefit seedlings; but because of their sensitivity, seedlings would be more prone to severe injury from intense light and frost. Therefore, in the absence of logs or stumps, live vegetation may be desirable as protective cover even though it competes with seedlings.

Hand scalping will probably be adequate for most planting operations. Aboveground parts of plants are totally removed, but lateral roots from vegetation surrounding the scalp usually remain active. Thus the zone of soil released from the competitive effects of vegetation tapers rapidly below the ground surface, and the extent of the soil column freed of competition depends on the size of the scalped area.

Site preparation with heavy machinery should not be attempted in the spruce-fir zone without fully considering management goals and potential effects on the site. Removing vegetative competition or treating slash for fire or bark beetle control can adversely affect plantation establishment by destroying microsites that afford protection for planted seedlings. Conversely, machines could be used to obtain better distribution of favorable microsites over the plantation by rearranging logs. Exposure of mineral soil during such operations would also create favorable seedbeds, which might result in supplemental stocking from natural regeneration.

In areas where hand scalping is unsatisfactory, vegetation may be controlled by such machine methods as disking, furrowing, mounding, ridging (berms resulting from plowing), and bulldozing. Where competing vegetation consists of relatively tall brush species that form dense cover, complete removal or cleared strips of bulldozer-blade width may be desirable. These machine methods have proven successful for other species, but they have not been thoroughly tested for Engelmann spruce plantings. The use of machines in wet areas to form mounds or ridges, to elevate roots above the water table, is not recommended for spruce planting, because the probability of regenerating such sites is low.

The effectiveness and suitability of different species of plants as protective cover for spruce seedlings is not fully known. Korstian and Baker (1925) noted that moderately dense stands of aspen (Populus tremuloides Michx.) without a heavy understory of shrubs and herbaceous plants were favorable sites for planting spruce. Observation of natural and artificial regeneration in several areas of the central Rocky Mountains showed that fewer live seedlings were found in the open than where they were protected by brushy plants—willows (Salix spp.) and potentilla (Potentilla fruticosa)—and tall herbaceous species such as fireweed (Epilobium angustifolium). These species, and probably others of similar growth habits, apparently can provide shade without seriously depleting soil moisture. The circumstances also suggest that precipitation and moisture-holding properties in some parts of the spruce-fir zone are not major considerations in determining the degree of site preparation needed.

In contrast, mortality of natural and planted spruce seedlings has been recorded where seedlings were established near clumps or between scattered individual plants of sedges and grasses, which spread to form a solid, dense cover with roots completely occupying the soil. Some mortality was attributed to root competition, and part to smothering by cured vegetation compacting under the weight of snow. The probability of regenerating areas with an extensive cover of dense sod is low, even with considerable effort and expense, and planting is not recommended.

Because of the diversity of site conditions, as well as financial and manpower limitations that may be encountered, each plantation must be **considered individually** to determine the degree of site preparation needed for best survival. Consequently, the following recommendations are presented as suggestions or alternatives.

Recommendations:

1. Plant recent cuttings and burns before they are invaded by meadow vegetation.
2. Regardless of the need for scalping or the method of treatment, save all microsites created by stumps, logs, and other material.
3. Hand-scalped spots should not be smaller than 18 to 24 inches square.
4. Machine-scalping with disks or plows (furrowing or ridging) should leave vegetation-free areas 1.5 to 2 feet wide.
5. Mounds, either machine or hand constructed, should be 14 by 14 by 7 inches minimum size.
6. Use willows, potentilla, fireweed, or plants of similar growth habit for protection only when inert objects are not available.
7. Underplanting in aspen groves should be limited to stands with moderate crown density and light cover of understory vegetation.

Planting

The primary consideration in planting is to obtain intimate contact between mineral soil and roots. Ideally, the technique for planting expensive ornamentals—spread roots over a mound of soil, carefully compacting soil around roots, and filling bowl around plant with water—would be best for bare-rooted spruce seedlings. Obviously, such a practice would not be feasible in operational plantings.

In many areas of the United States where soils, topography, and environmental conditions are favorable, machines and planting bars have proven successful. In the spruce-fir zone, however, such flexibility is normally not possible. Machine planting would not only be impractical because of interference from rocks and roots in the soil, and objects on the surface needed for protection, but soil compaction around seedling roots also would not be sufficient. Slit planting can be used in light or medium soils, but in heavy soils found on some spruce sites, the combination of poor compaction and a harsh environment would reduce survival.

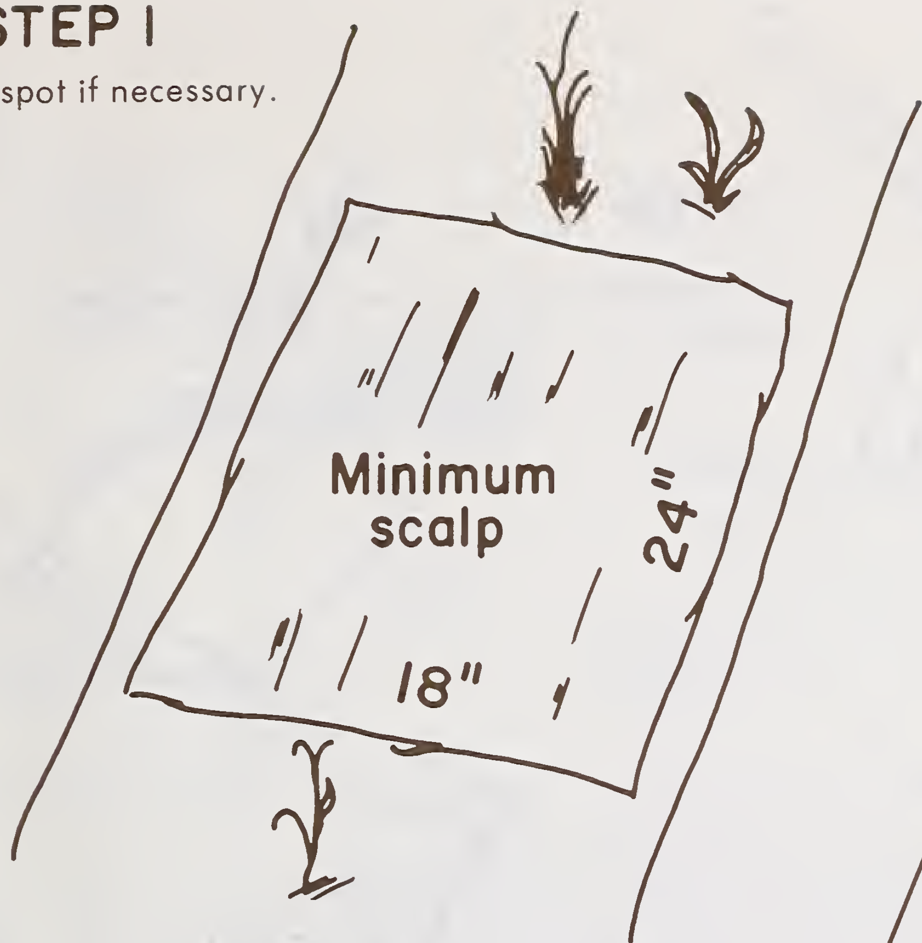
The hole method is preferred for planting spruce, since it resembles the technique used for ornamentals if properly done. Holes are generally dug with planting mattocks, but power-driven augers have proven satisfactory in lighter soils free of dense roots and rocks, and covered with little or no litter. Regardless of the type of digging tool used, techniques for setting seedlings in holes are similar. Power-auger operators, however, should be cautioned against digging holes so far in advance of planters that excavated soil dries before seedlings are set.

Recommendations:

1. Use the hole method; dig holes with mattock hand-tools, or power augers where soil conditions permit.
2. Insist that planters do professional work as illustrated in the following steps:

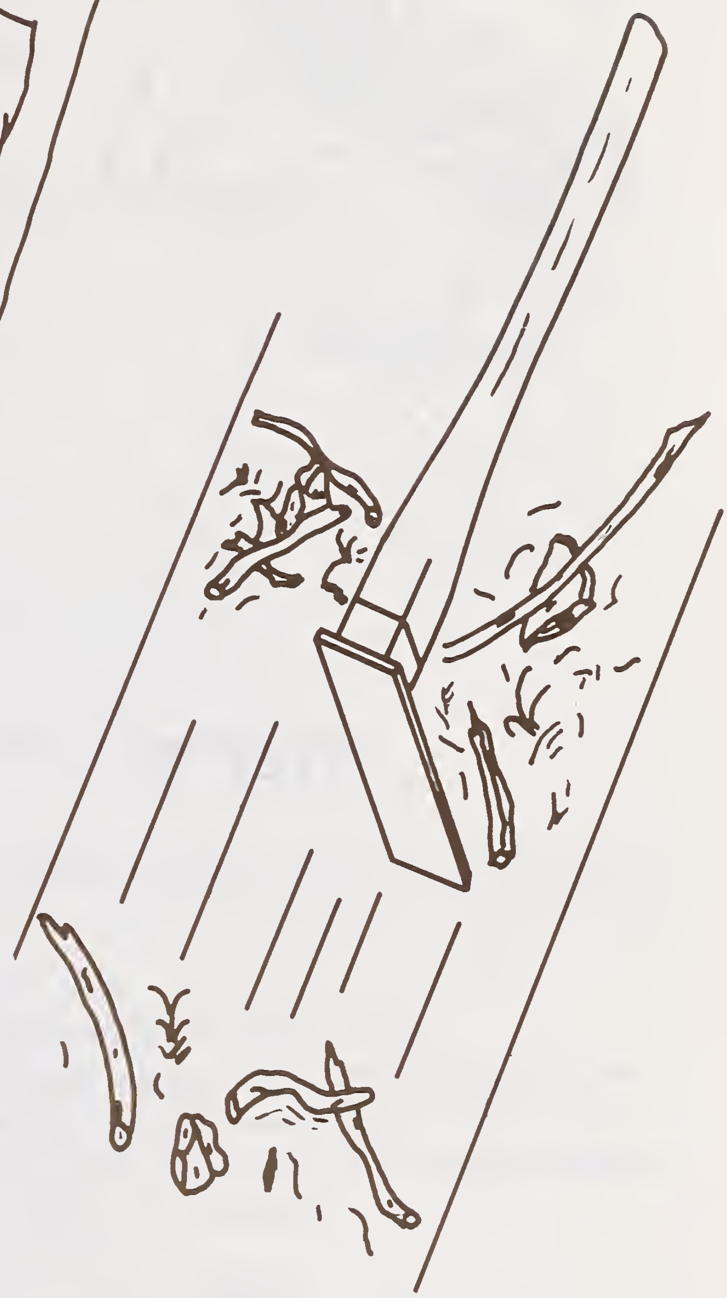
STEP 1

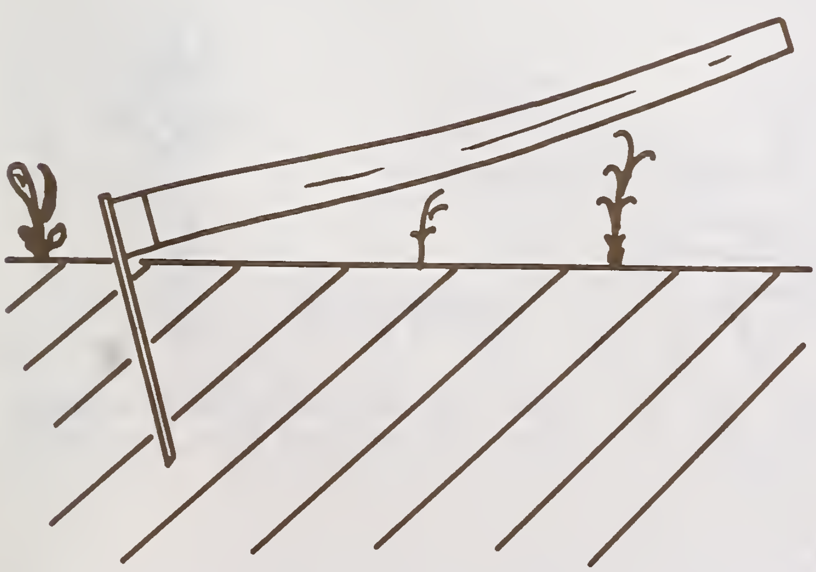
Scalp spot if necessary.



STEP 2

Remove live vegetation, litter, dry soil, or other debris from surface of spot with mattock to eliminate material that may fall into the hole and prevent intimate root-soil contact when hole is refilled.



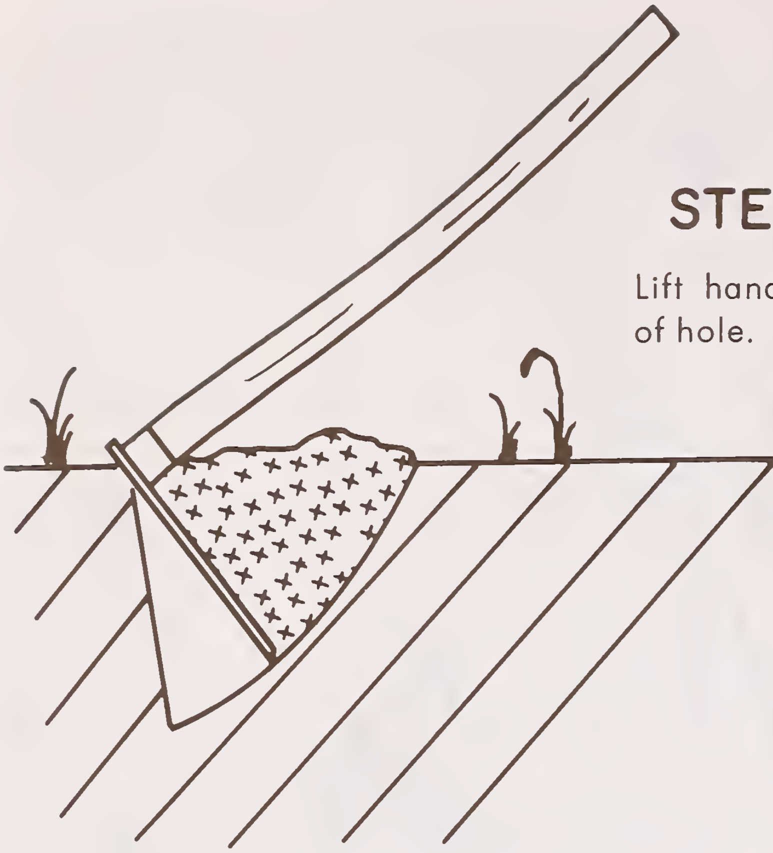


STEP 3

Swing mattock with sufficient force to bury blade to full length in one or two swings; leave blade in soil after final swing.

STEP 4

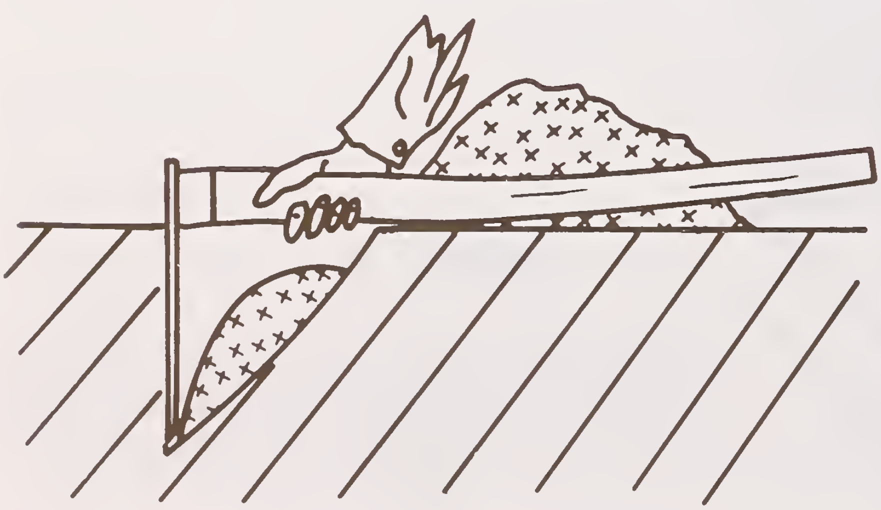
Lift handle sharply to break soil at bottom of hole.



STEP 5

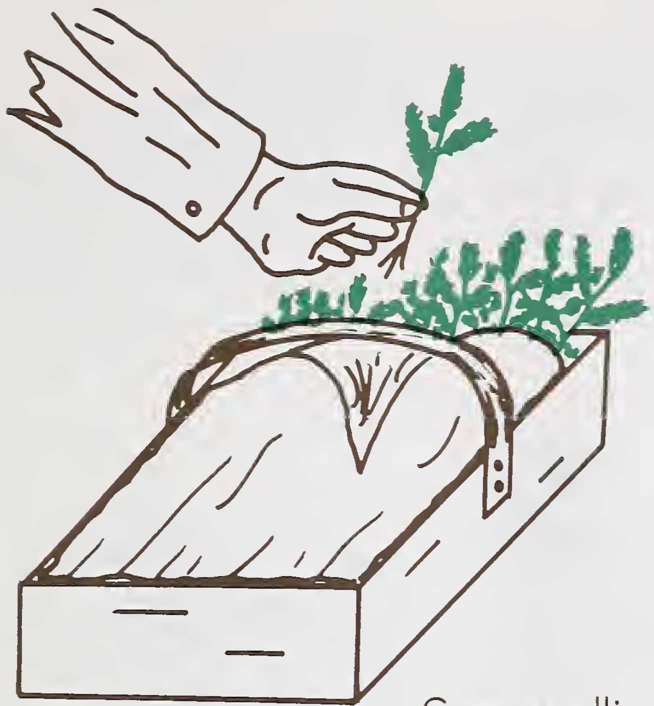
Pull loosened soil into a compact pile near front of hole.

STOP. Do not plant if hole is not in mineral soil—duff, humus, and rotten wood dries rapidly and compacts poorly around roots.



STEP 6

Trim rear wall of hole to vertical, using a shortened grip on mattock.



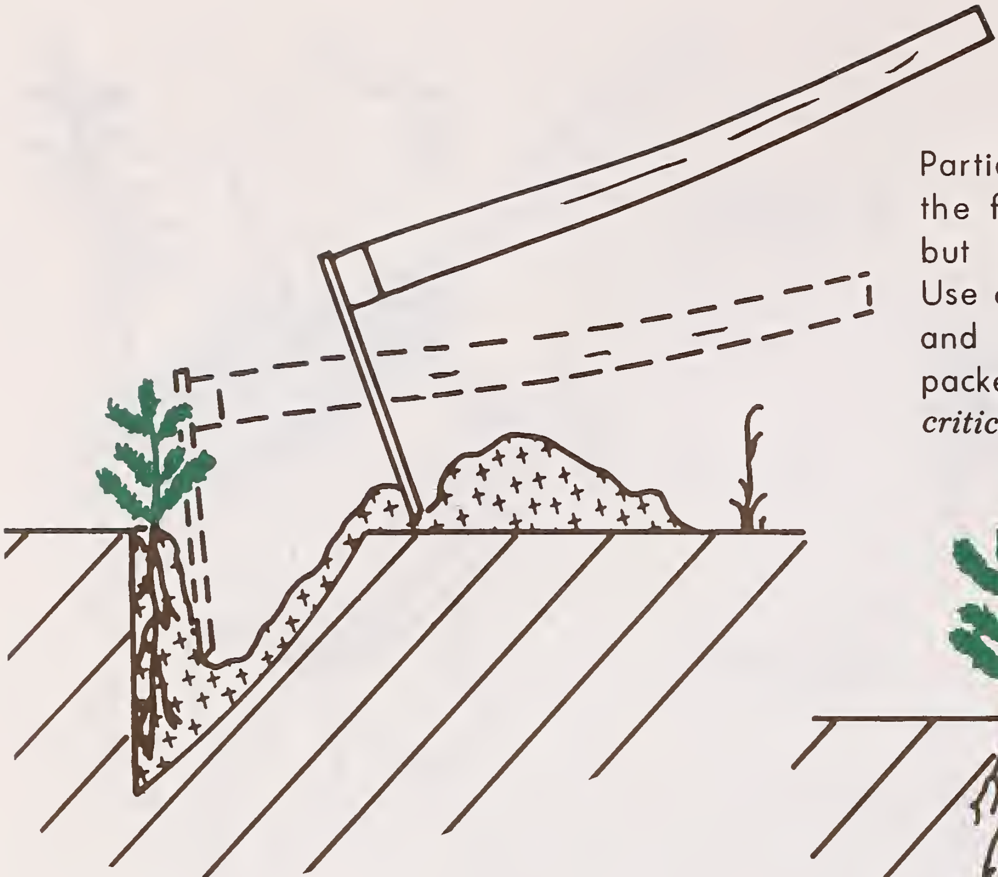
STEP 7

Grasp seedling stem near root collar—do not pull on foliage—and remove from tray or bag carefully to prevent tearing intertwined roots. Remove one tree only, and be sure that roots of seedlings in container remain covered. Do not expose seedling before hole is dug.

STEP 8

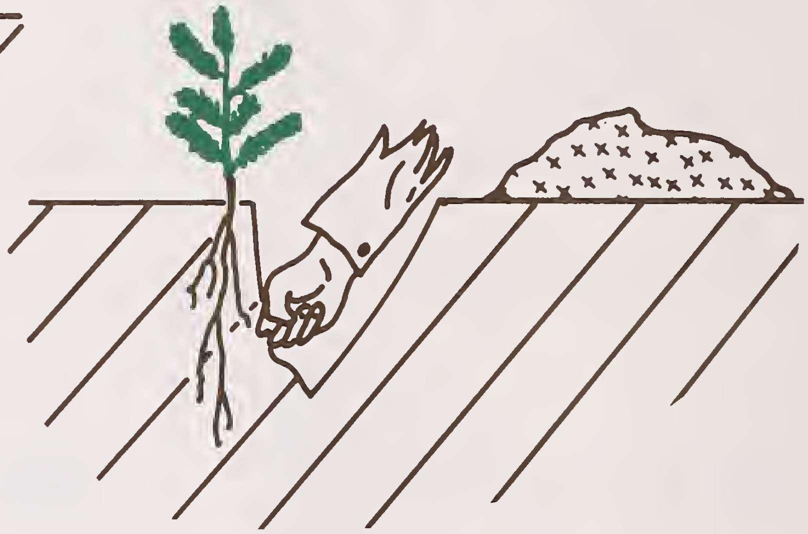
Spread roots against rear wall of hole with root collar at or slightly below ground level.

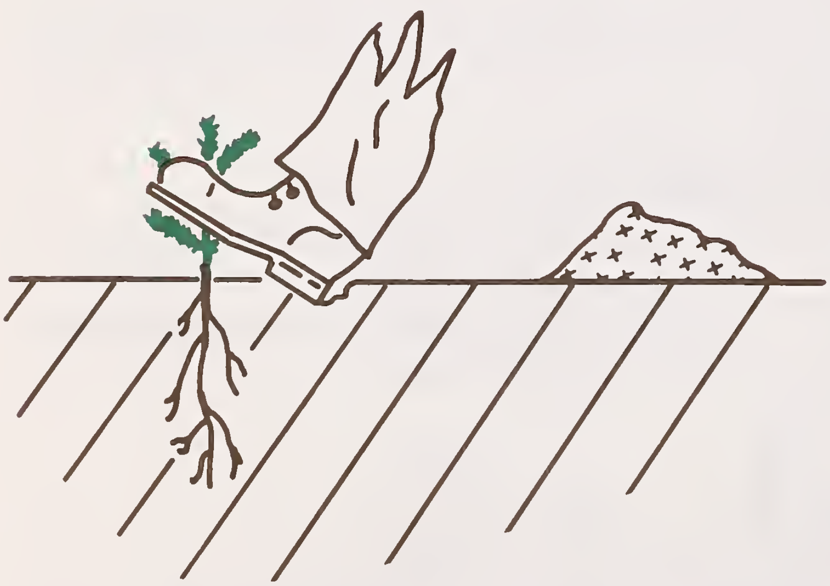
Be certain roots extend vertically and are not L-, J-, or U-shaped.



STEP 9

Partially fill hole with *moist* soil and, using the fist or toe of the mattock, pack firmly but *carefully* to prevent injury to roots. Use only enough soil—freed of large stones and any accumulated debris—to form a packed layer about 1 inch thick. *This step is critical for intimate soil-root contact.*





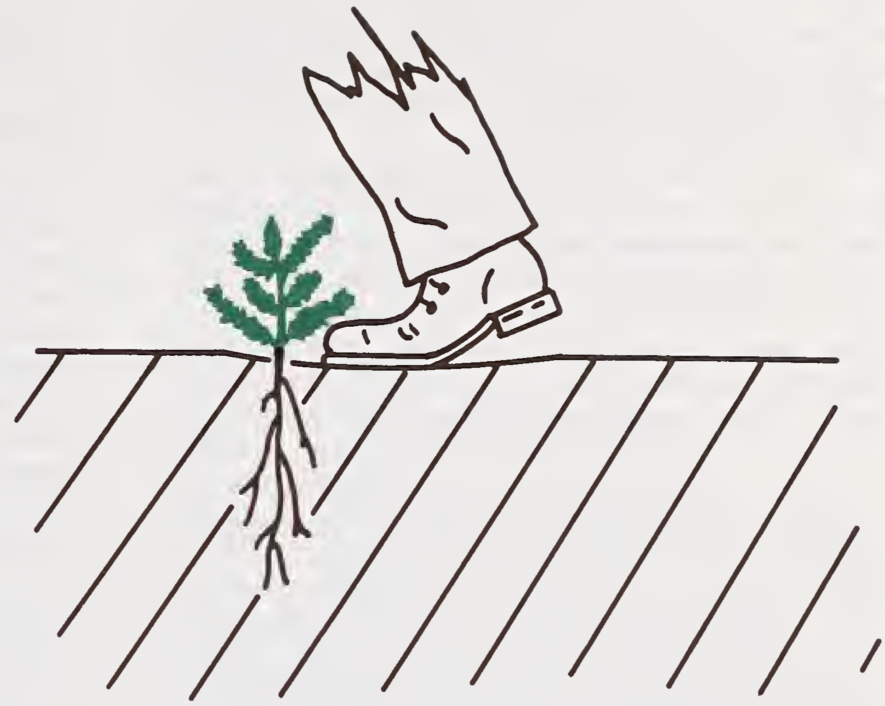
STEP 10

Fill hole with *moist* soil and pack firmly using the heel of the mattock or boot heel; usually three or four tamps are sufficient.

Soil is properly packed when tree cannot be pulled from hole easily.

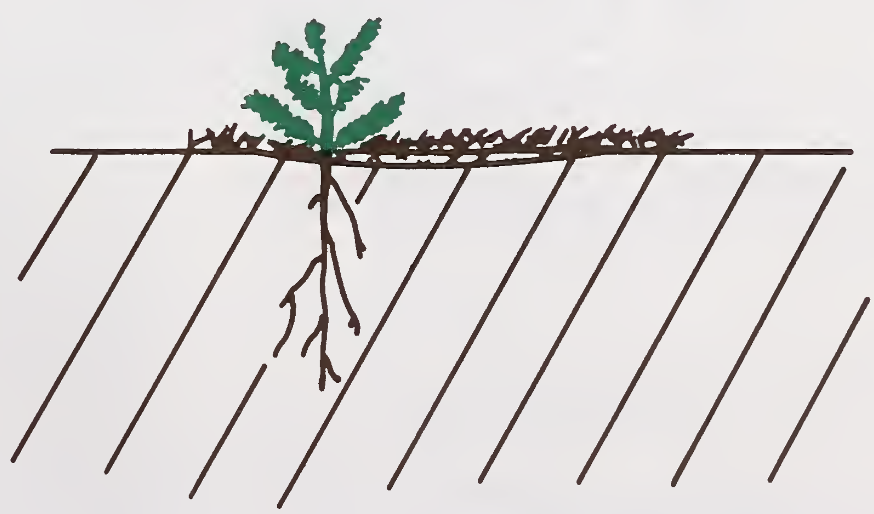
STEP 11

Fill deep depressions left by scalping or packing and firm soil around seedling.



STEP 12

Cover planting spot with a mulch of *loose* soil or litter to reduce evaporation. Whenever practical, arrange logs or slash for added protection against solar radiation (figs. 1A, 1B, 2D, 5).



Plantation Protection

During the juvenile stage, seedlings in plantations are exposed to many hazards which are more difficult to assess and eliminate than those encountered before planting. Nevertheless, these hazards must not be neglected if reforestation is to be successful. They include such environmental and biotic factors as frost, intense solar radiation, rodents, snow-mold fungi, and large animals.

In some instances these factors may be the immediate cause of mortality, but often seedlings are progressively weakened by several causal agents and subsequently die. For example, mortality was high in a newly established plantation when current growth was killed by summer frosts in 4 of 6 years, and part of the remaining foliage was killed by snow mold during 4 winters of the same period.

Most rodent injury of spruce seedlings is caused by mountain pocket gophers (Thomomys talpoides). Although some mortality is likely every year from girdling, severing the stem, or from burrowing activity, losses are highest during peak population years. Mice have been observed to girdle associated species extensively, but only scattered damage has been reported for spruce seedlings.

Information regarding the magnitude of large animal damage in spruce plantations is limited (Roe et al. 1970). Generally, grazing is not the immediate cause of mortality, unless seedlings are severed below live branches. The adverse effect of grazing is reflected by loss of seedling vigor; the photosynthetic capacity of seedlings is reduced as foliage is browsed. Spruce seedlings, because of their small size, are particularly vulnerable to trampling. Not only is photosynthesis reduced as branches are broken off, but the flow of nutrients and water is disrupted by crushed stem tissue, which may be severe enough to cause direct mortality. The worst feature of grazing is that it is repeated year after year, and when coupled with injury from other sources, the chances for survival are limited. Cattle appear to cause less damage to plantations than sheep, but successful plantations have been observed on sheep allotments where seedlings were protected by down timber.

Recommendations:

1. Avoid planting in frost pockets—temperatures are likely to be so severe that normal protective cover will not prevent injury.
2. Avoid planting in areas where advanced regeneration shows high incidence of snow mold.
3. Initiate a rodent survey program, and control animals when populations build up.
4. Grazing should be prohibited until seedlings reach a height of at least 3 feet to prevent trampling damage. Light grazing could then be permitted, providing concentrations of livestock can be avoided. If systematic observations disclose browsing damage, then grazing should be discontinued until terminal buds are beyond reach of livestock.

Records

Adequate data from detailed records are needed to (1) correct deficiencies causing failure, and (2) recognize good practices leading to successful plantations. Decisions affecting regeneration practices can then be based on quantitative information rather than conjecture.

The following recommendations are suggested for minimal records; individual preference or circumstances may justify others.

Recommendations:

1. Provide a record of plantation establishment: (1) location; (2) size; (3) species planted; (4) kind of stock (age, size, quality, or grade); (5) seed source; (6) planting dates; (7) method of site preparation and equipment used; (8) method of planting and kind of tool used; and (9) density of planting.
2. Maintain continuous thermograph record of temperatures during transit and local storage.
3. Use staked trees to obtain continuous detailed information:
   a. Stake at least 100 trees in small plantations, and 1.5-2.5 percent of total planted in large plantations.
   b. Staked trees should be alined across the direction of travel to sample variation due to planters.
   c. Staked trees should be alined roughly perpendicular to the contour to sample topographic variation.
4. Determine course of plantation establishment by recording survival at the end of the first, and the beginning of the second and third growing seasons.
5. Identify and record cause of mortality or injury to staked seedlings.
   a. Rodent girdling or severing of the stem can usually be identified (mice, gophers, or porcupines) by the relative size of incisor tooth marks left in woody tissue.
   b. Frost injury can be recognized within a few days after freezing by the limp, wilted appearance of current growth. The current foliage later turns a light tan or straw color, regardless of the stage of development of the shoot. Older foliage shows no visible injury.
   c. Solarization is most easily detected by the yellow or yellowish-green foliage—symptoms appear first in older foliage, but chlorosis is often evident in current growth by the end of the growing season.

d. Snow mold pathogens are readily identified by the dense, brown or brownish-black, mycelial mat formed over individual branches or entire seedlings.
e. Drought injury can be recognized by the faded, light-green or blue-green needles which are dry and brittle, and usually drop off; undeveloped current-year shoots may wilt under severe dehydration. After the seedling has died, any remaining needles usually turn a dark, reddish brown within 7 to 10 days if soil moisture becomes available.
f. If seedlings show drought symptoms, the cause can sometimes be traced to improper planting—loosely packed soil or doubled roots.
g. Browsing damage by wildlife or livestock can often be determined by the frayed or splintered appearance of severed branches.
h. Trampling injury caused by large animals is evident from broken foliage and tracks near seedlings.

6. Record vigor of staked seedlings as poor, fair, good, or as otherwise desired, which can be used as a measure of plantation success along with survival data.
7. Measure or estimate precipitation and general weather conditions for several weeks after planting.
8. Record, and most importantly, file data in such a manner that personnel not immediately involved with the specific plantation can use the information most effectively.

Summary

Spruce plantations can be established, but the job will not be easy. The task is not impossible, however, as recently demonstrated in operational plantings on the San Juan National Forest, if there is full realization that none of the planting operations can be lightly considered or haphazardly conducted. Satisfactory regeneration can be obtained, but planting costs will be higher than ever before, since many of the recommendations will increase supervision, require more specialized equipment, or lower daily production. Nevertheless, the cost will almost certainly be less than replanting.

Once the decision is made to reforest nonstocked land, emphasis must be placed on getting maximum survival rather than getting seedlings in the ground at the lowest cost. Cost accounting cannot be disregarded, but a more realistic method of evaluation must be applied, especially when regeneration is exceptionally difficult and costly. Consequently, success in spruce plantations should be measured by the amount invested for an established tree, and not the commonly applied criterion of planting cost per acre.

Expected survival cannot be precisely predicted, because the impact of numerous environmental factors on newly established plantations varies from year to year. Studies indicate, however, that 75 percent of the planted seedlings can reasonably be expected to become established if catastrophic losses from factors such as gophers and snow mold can be prevented or avoided (Ronco 1970b).

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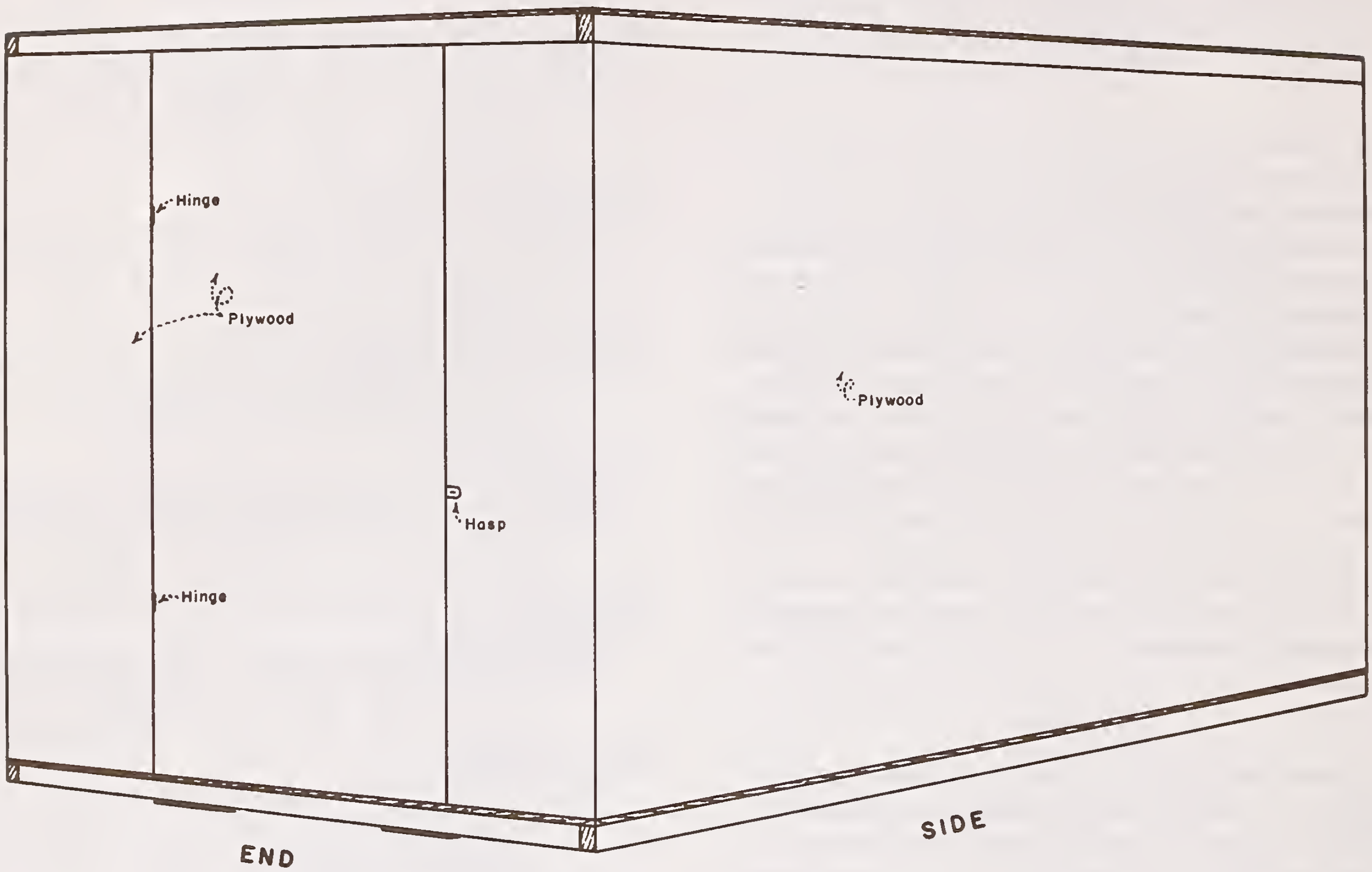
Appendix

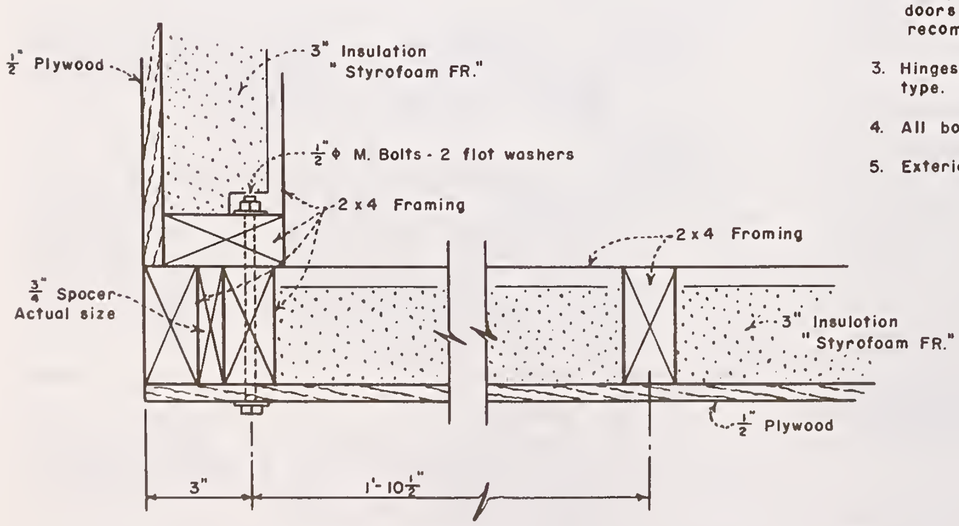
Construction plans for portable building used in Rocky Mountain Region, (Region Two), U. S. Forest Service for temporary cold storage of tree seedlings on the planting site.



TREE STORAGE BUILDING

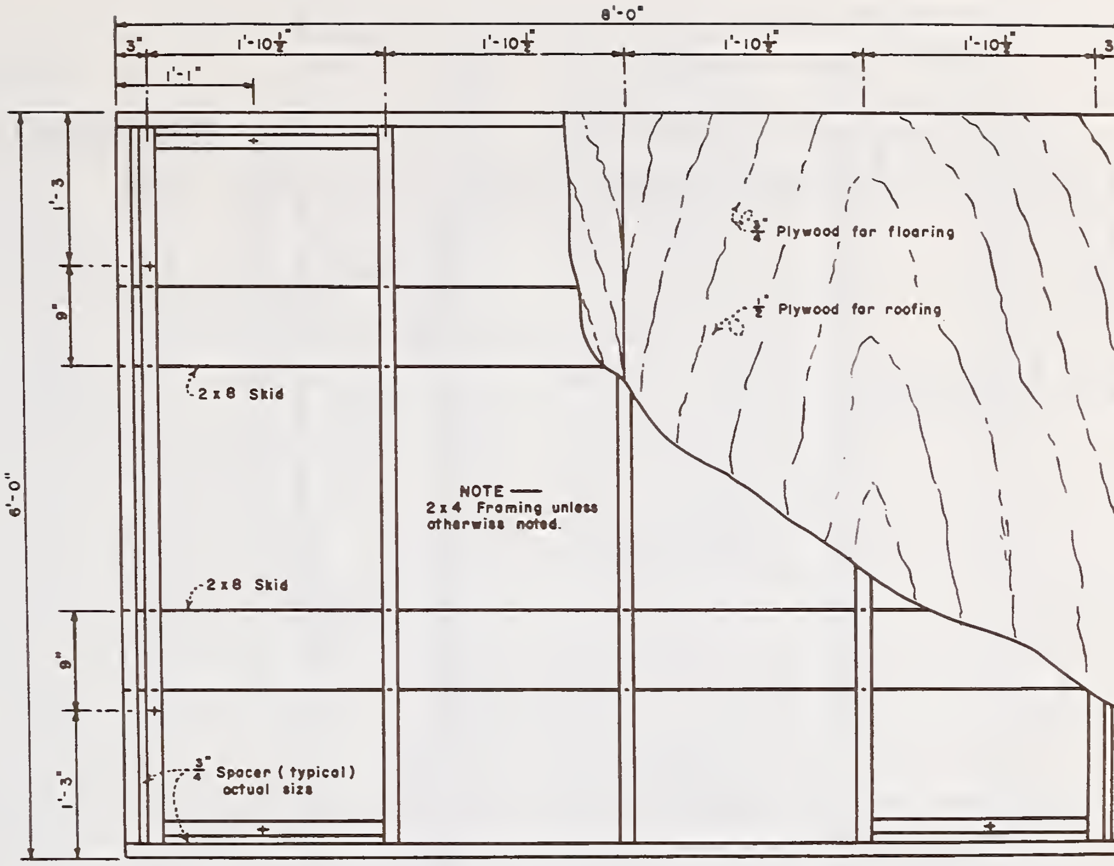
NOTES

1. All plywood shall be exterior grade.
2. Insulation shall be 3" thick, applied between framing on sides, ends, roof and below flooring. Also to the $\frac{1}{8}$" hardboard on doors as shown in Section A-A. Adhered in place with adhesive recommended by the manufacturer.
3. Hinges shall be butt, loose pin type. Hasp shall be safety hinged type.
4. All bolt holes to be drilled $\frac{1}{16}$" larger than bolts to be used.
5. Exterior of building shall be painted white.



TYPICAL CORNER FRAMING

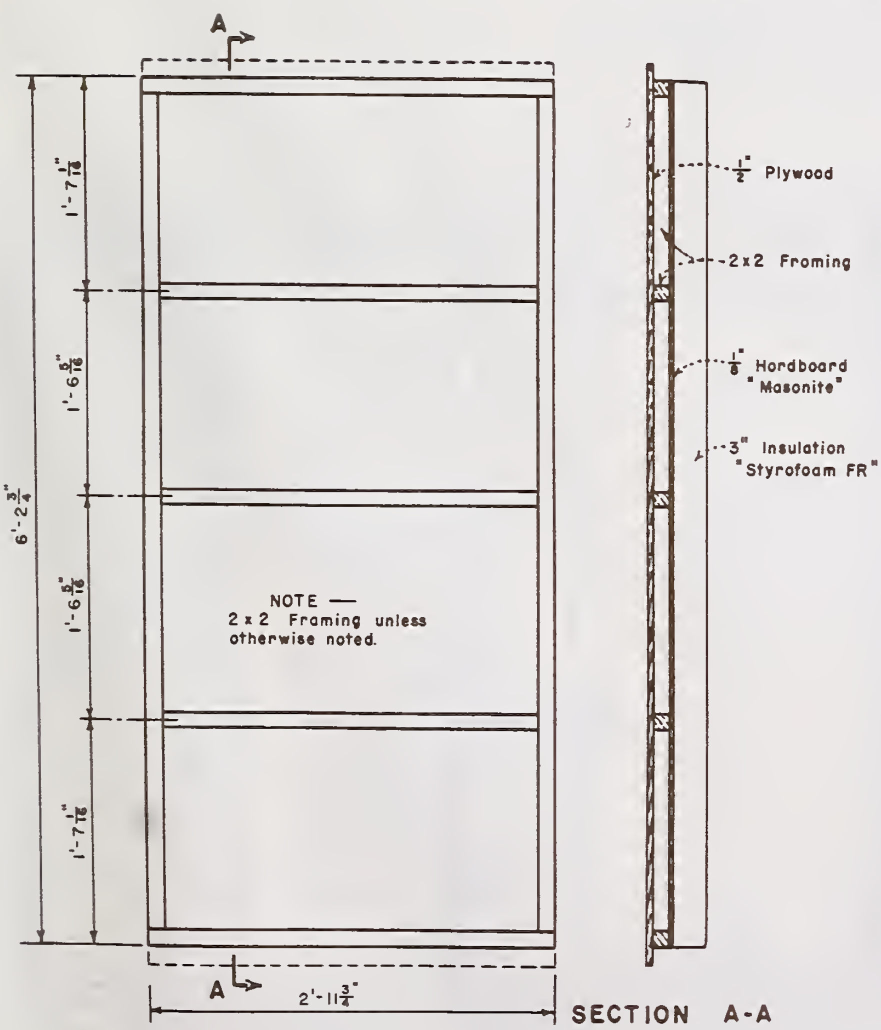
Scale 3" = 1'-0"



BASE PLAN - TYPICAL FRAMING

Scale 1" = 1'-0"

NOTE – The Top framing is similar as Base except ½" plywood used as roofing and 2 x 8 skids to be omitted.

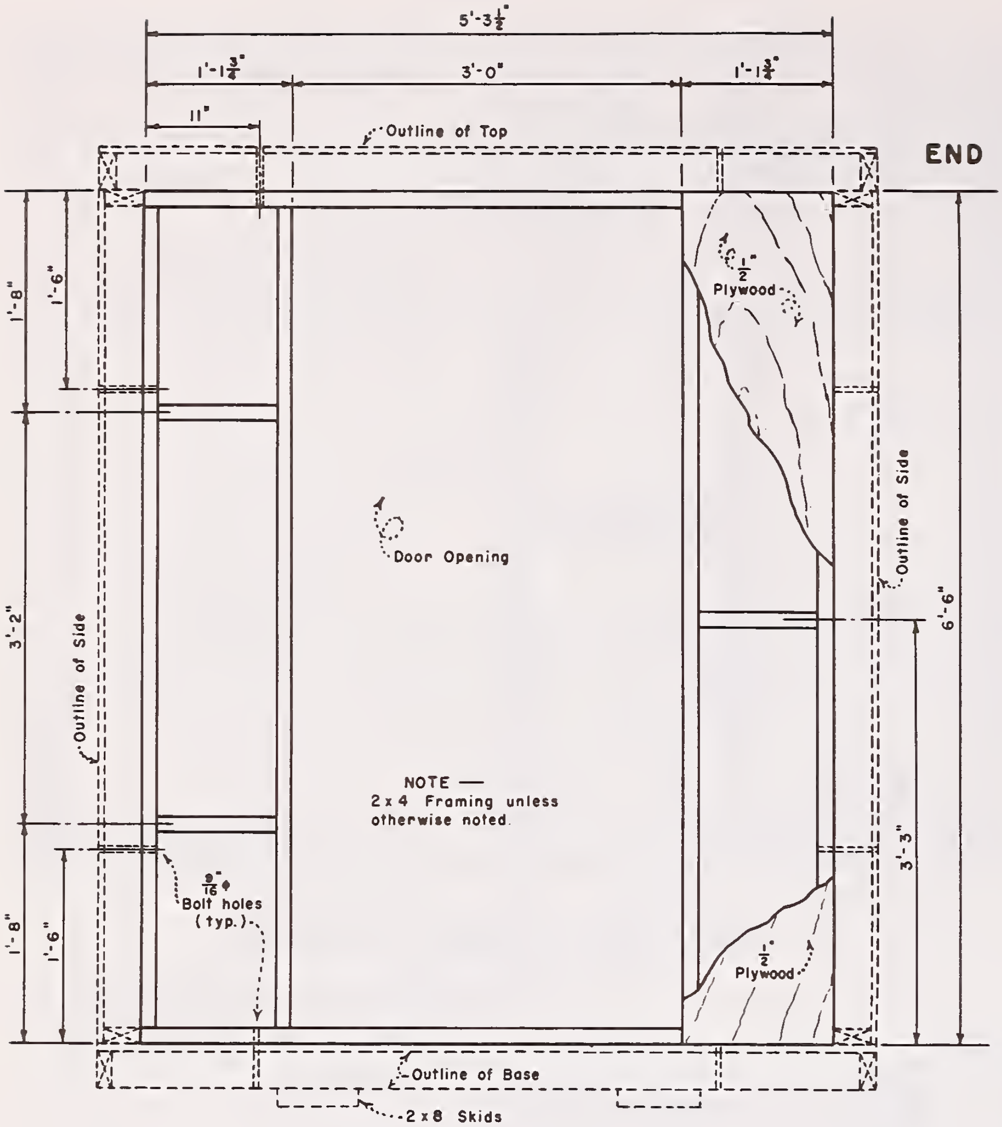


ELEVATION

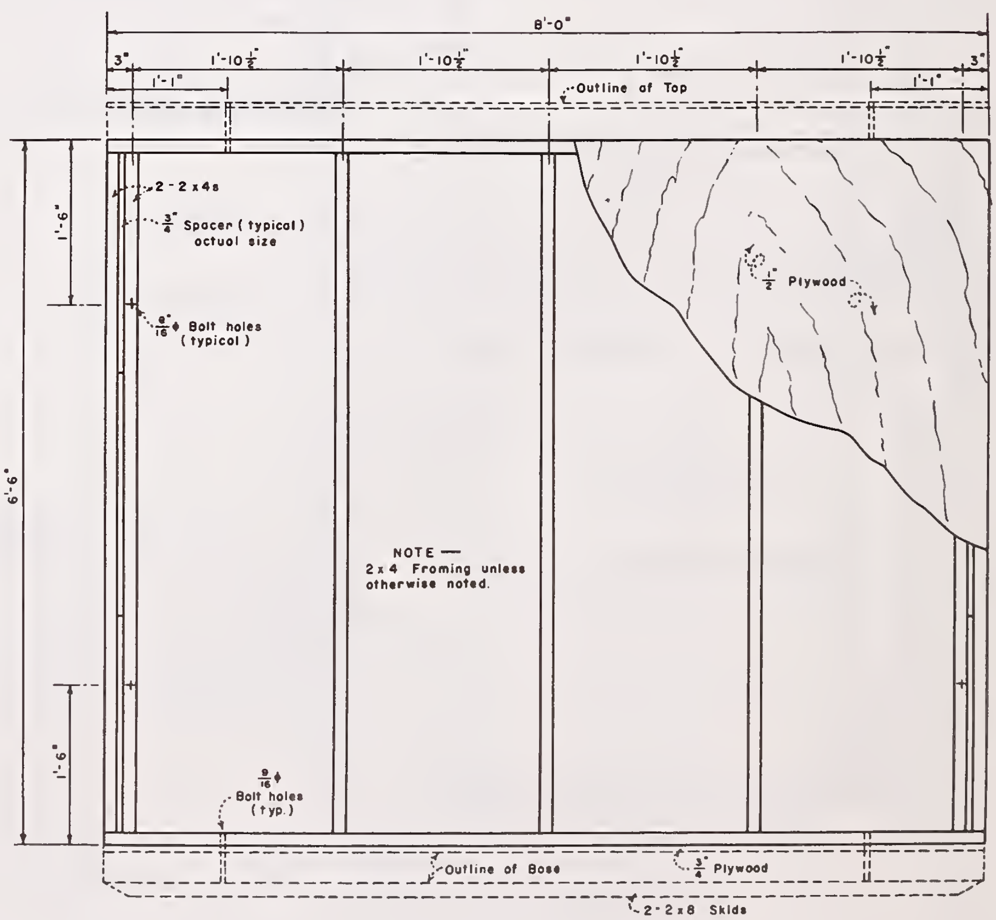
SECTION A-A

DOOR - TYPICAL FRAMING

Scale 1" = 1'-0"



END ELEVATION - TYPICAL FRAMING
Scale 1" = 1'-0"



SIDE ELEVATION - TYPICAL FRAMING
Scale 1" = 1'-0"

Agriculture—CSU, Ft. Collins

Ronco, Frank.
1972. Planting Engelmann spruce. USDA For. Serv. Res. Pap. RM-89, 24 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Recommendations are provided to aid the forest manager in regenerating Engelmann spruce by planting in the central and southern Rocky Mountains. Reforestation operations covered include storage, transportation, microsite selection, site preparation, planting, plantation protection, and recordkeeping. The physiological and silvicultural requirements of spruces are discussed with respect to the harsh environment of the spruce-fir zone so that planting principles can be better understood.

Keywords: Picea engelmannii, planting, artificial regeneration.

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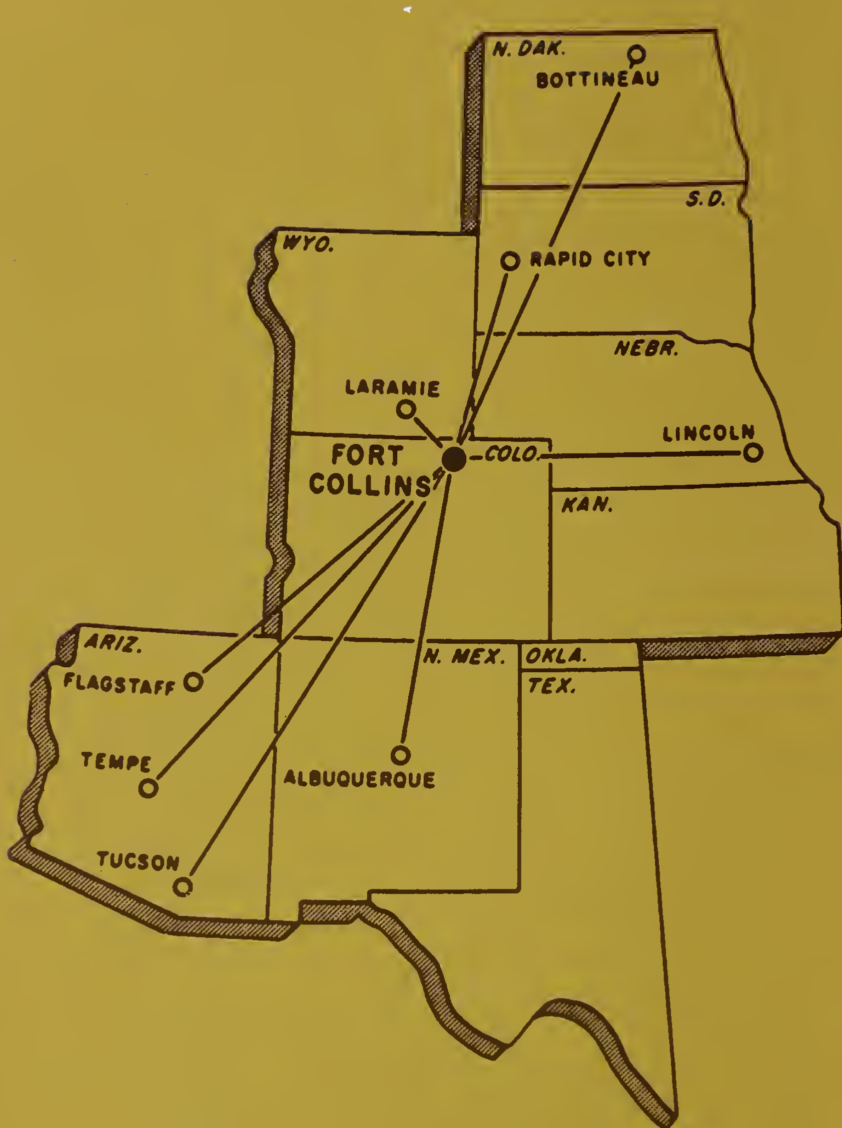
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BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
FORT COLLINS
COLO.
LINCOLN
KAN.
ARIZ.
FLAGSTAFF
N. MEX.
OKLA.
TEX.
TEMPE
ALBUQUERQUE
TUCSON